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Caring for musicians' ears: Insights from audiologists and manufacturers reveal need for evidence-based guidelines.

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Abstract

Objective: This study investigated clinical care delivered to musicians in Australia by audiologists and manufacturers of musicians'hearing protectors. *Design*: Audiologists with experience treating musicians were invited to complete a survey on their service delivery. A second survey was administered to manufacturers of musicians' hearing protectors (MHP). *Study sample:* Four manufacturers of MHP and 31 audiologists completed the surveys. Post-hoc analyses were performed comparing the responses of audiologists with more versus less clinical experience; and those with and without musical training. *Results*: There was considerable variation in the audiological care provided to musicians. Only one-third of audiologists performed pure-tone audiometry prior to MHP fitting, and there was little consistency across the sample in relation to impression taking, preferred attenuation or selection of canal length. There was also significant variation in the manufacturers' approach to MHP, each of whom provided different recommendations regarding preferred impression techniques and material viscosity. *Conclusions*: The results of this study reveal lack of consistency across the hearing healthcare sector with respect to care of musicians' hearing, with potential to impact upon the satisfaction with, and usage of, MHP. There is need for evidence-based, best practice guidelines and training to support clinical audiologists in providing optimal care.

Key Words: Hearing conservation/Hearing Loss Prevention; Noise; Tinnitus; Demographics

Abbreviations: MHP, Musicians' hearing protectors; NIHL, Noise-induced hearing loss; PTA, pure-tone-audiometry.

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Introduction

Hearing loss is the second most common health disability in Australia, affecting one in six individuals to varying degrees (Access Economics, 2006). For a significant proportion of these individuals, their hearing loss is a result of cumulative exposure to loud sound. Known as noise-induced hearing loss (NIHL), it is one of the leading forms of workplace injury (Nelson et al, 2005). It is characterised by a permanent sensorineural hearing loss, typically with a notch at 3-6 kHz, and often occurs in association with other symptoms such as tinnitus (Axelsson & Sandh, 1985; Bergström & Nyström, 1986). The sensorineural loss, which is due to damage to the auditory hair cells in the cochlea, is the result of a combination of the sound pressure level , the duration of exposure, and the frequency of exposure (Kurabi et al, 2016).

According to Australian workplace health and safety standards, if noise levels exceed 85 dB L_{Aeq} over an 8-hour work day, exposure time should be halved for every 3 dB increase to minimise hearing injury in workers (Standards Australia, 2005). There is discussion as to whether the same standards should apply in the music industry. Some argue that because music is not steady-state broadband industrial noise, but rather highly variable in terms of its dynamic range and frequency components, it may be appropriate to develop music-specific exposure standards that consider these differences (Staff-AES, 2006). Nevertheless, the 85 dB/8-hour exposure limit is the only damage-risk criteria currently available, and there is ample evidence that musicians and those regularly exposed to loud music are at increased risk of hearing injury and NIHL. (Patel, 2008; McIlvane et al, 2012; Pouryaghoub et al, 2017).

Studies of sound exposure of musicians have demonstrated that sound levels in the music industry regularly exceed levels that in the industry workplace would be considered unsafe and be subject to regulation due to the potential for damage to hearing (Kahari et al, 2003; Zhao et al, 2010). For classical musicians, on-stage sound levels of up to 111 dBA have been recorded (Camp & Horstman, 1992), with individual exposure varying greatly based on music genre and positioning on stage

(O'Brien et al, 2008). High sound levels at pop/rock concerts have also been found, with 100 dBA levels common (Yassi et al, 1993; Opperman et al, 2006; Einhorn, 2006). At this level of exposure an individual's daily noise limit is reached within just 15 minutes. The potential for high levels of exposure extend to rehearsal spaces, with one study finding rock musicians experienced levels between 90 and 96 dBA in this environment (McIlvaine et al, 2012).

Kahari et al (2003) estimated that some 74% of musicians experience at least one symptom of hearing injury, be it hearing loss, tinnitus, hyperacusis, distortion or diplacusis. Tinnitus in particular is reported to be common in musicians, with estimates ranging from 17% to 54% of musicians, whereas the incidence of tinnitus in the general population is around 10% (see review by Patel, 2008;Homes & Padgham, 2011). However, conflicting results have also been reported, with some studies reporting minimal impact of music upon hearing thresholds, whilst others report significant evidence of risk (Karlsson et al, 1983; Axelsson et al, 1981; Cunningham et al, 2006). More recently, it has been reported that there may be damage from noise/music exposure without the presence of a permanent hearing threshold shift, indicating that musical exposure can lead to degradation of the hearing pathway when over-exposure occurs (Kujawa & Liberman, 2009; Schaette & McAlpine, 2011; Otsuka et al, 2016).

In addition, symptoms such as tinnitus or permanent hearing loss can lead to secondary effects on quality of life such as depression, anxiety, or social isolation (Strawbridge et al, 2000; Mohamad et al, 2016). For a musician, the effects of NIHL impact both on their professional and recreational pursuits, leaving many feeling a sense of detachment from, or fear towards, music. For instance, Størmer et al, (2015) reported that 27.2% of rock musicians with tinnitus had considered quitting their profession specifically because of their hearing problems including tinnitus. Furthermore, Wills & Cooper (1988) reported jazz and pop musicians rated the health consequences of heavily amplified music as their sixth most significant work-related stress. With this in mind, it is imperative that musicians, who are at greater risk of hearing damage because of their high exposure levels, are

offered appropriate and targeted audiological care, to assist them in making informed choices about hearing protection solutions.

Standard commercial hearing protectors, such as those designed for the workplace, are in general inappropriate for use by musician clientele. The common foam earplug, for example, can both over-attenuate and distort the musical sound, muffling high frequencies more so than lows, making it difficult for musicians to ensure the quality of their performance (Chasin, 1996; 2009). To this end, musicians' hearing protectors (MHP) have been developed to attenuate sound as evenly as possible across audible frequencies (Killion, 1988). In custom-moulded earplugs, this is achieved firstly by use of a hollow sound-bore in the centre of the plug, which acts as an acoustic mass. A thin diaphragm, or filter, is then attached to the external portion of the plug, whose stiffness helps dictate the degree of attenuation offered by the hearing protector. While the degree of attenuation can vary across MHPs provided by different manufacturers, it is typically, in the 9-25dB range. When the earplug is inserted into the musician's ear, their natural canal resonance is lost, yet the combination of both acoustic mass and filter help compensate for this and aid in achieving the flat attenuation (Killion, 1988).

Research has found the use of hearing protection by musicians to be consistently low in spite of many advances in technology (Laitinen & Poulsen, 2008; O'Brien et al, 2014). A study of 429 German symphony musicians for example, showed that even though 82.6% of musicians were aware of custom MHP, just 8.4% used them during rehearsals and only 7.2% reported using them 'often' or 'very often' during a performance (Zander et al, 2008). Dissatisfaction with hearing protectors often hinges upon issues such as their perceived negative effect on musical performance, disengagement from other musicians on stage, physical discomfort or distortion of sound due to occlusion of the ear canal (in which low frequency sounds 'trapped' in the ear canal can become audible(Laitinen, 2005; Killion, 2012; O'Brien et al, 2014). However, additional factors such as training of musicians in the use of ear plugs, allowing time for musicians to acclimatise to use of musicians earplugs, and ensuring

audiological support for this use may all have a significant, positive impact (Huttunen et al, 2011; Casali & Lee, 2017).

Although there is a considerable literature on the technical aspects of MHP and barriers to their use, the focus has tended to be on the role of musicians in using MHP, rather than hearing professionals in recommending and/or counselling on their use. For this reason, our study focus was to investigate the role of the hearing healthcare sector, including both audiologists and manufacturers, in relation to musicians and MHP. More specifically, we were interested in understanding the standard of hearing care delivered to musicians in Australia, any variation in delivery, and the extent to which the practices of audiologists and manufacturers overlap. To achieve these aims, two exploratory surveys were developed, one for audiologists and one for manufacturers experienced in the creation or delivery of custom MHP in Australia.

Methods

This study was conducted under the ethics approval and oversight of the University of Melbourne's Human Research Ethics Sub-Committee.

Materials

Two survey instruments were developed: one for use with audiologists who were experienced in fitting MHP, and a second for use with manufacturers of MHP in Australia. For the purpose of this study, MHP referred to any custom-made product fit with a filter designed to give the wearer flat attenuation of sound. The audiologists' survey covered technical issues such as impression technique and materials, as well as areas of professional practice, such as protocols and practitioner confidence. The manufacturer survey focused on the company's methods of producing and verifying MHP, as well as their recommendations for audiologists on technical aspects. Both surveys included open- and closed-response items to encourage dialogue on the topic, and are shown in Appendices 1 and 2.

Procedure

Each survey was delivered to participants via an online survey platform (SurveyGizmo, Boulder, Colorado). Prior to completing the survey, participants were provided with information about the purpose of the study, and advised that all responses would be kept confidential. Informed consent was then obtained from each respondent. Although participants were not required to provide any identifying information in the survey, all contact information (e.g., email addresses) which could be used to identify participants was stored separately from the survey responses to ensure confidentiality and privacy for all audiologists and manufacturer representatives. No inducements or rewards were provided to participants.

Recruitment

Audiologists were recruited via email invitation sent directly to hearing clinics throughout Australia. A copy of the link to the survey was also sent to 2500 members of Audiology Australia via the organisation's e-newsletter. The five manufacturers of MHP in Australia were identified, and all were invited to participate individually via email. Follow-up phone contact was made where required.

Participants

Thirty-one audiologists responded to our invitation and completed the online survey (male = 41.9%, female = 58.1%). Age ranged from 26 to 64 years (mean = 38.7, SD = 11.8) with an average of 12.9 years' clinical experience (range = 1 – 40 years). Just under one-third of the participants identified their role as management, and three as researcher. Previous musical experience was relatively high, with 77.4% having learnt an instrument at some stage, and almost half (48.4%) had performed professionally or semi-professionally. Most audiologists worked in metropolitan clinics (74.2%), while the remainder worked in a rural setting. Around one-third of the audiologists reported that there was a pre-existing relationship between their clinic and a MHP manufacturer, and four participants had a formal relationship with a professional music body (such as an orchestra).

Four of the five manufacturers approached agreed to be involved in our study, and the survey was completed by a company representative nominated by the manufacturer. Each manufacturer

confirmed prior to involvement their engagement in the music industry and experience with providing MHP. Each manufacturer had experience manufacturing at least one type of MHP, but for the purposes of this study, the focus was on custom-moulded, filtered MHP only. The manufacturers' average years of involvement in making MHP was 22.4 years (range = 11 – 31 years). Two of the companies had connections with music-related bodies, such as hearing health organisations or orchestras.

Data Analysis

Descriptive statistics were used to further explore answers to closed response items from the survey questionnaires (appendices 1 and 2). For open-ended response items, answers were coded into appropriate categories and these were ranked in order of occurrence for each question. In order to investigate if years of clinical experience or previous musical training (semi-professional or professional) influenced any of the audiologists' response outcomes, Pearson's and likelihood ratio chi-squared tests were used.

Results

Audiologist Survey

Professional Practice

The majority of audiologists felt confident in their ability to provide hearing care for musicians, with 27 (87.1%) reporting moderate or high confidence, and only four expressing slight confidence in the task. Despite this, 25 participants (80.7%) said they would find an upskilling course on the topic of musicians' hearing care helpful to some degree, whilst six did not.

Audiologists were asked if a protocol for the hearing care of musicians was established in their clinic. While nine respondents (29%) indicated this was so, the description of these protocols ranged from guidance on impression technique to inclusion of extended diagnostic assessments. To clarify this, audiologists were asked to indicate which assessments were routinely included in their test battery

when assessing musicians for hearing protectors (see table 1). By far the most common procedure was otoscopy, included by all respondents, followed by pure-tone-audiometry (PTA) up to 8 kHz (performed by 11 audiologists (35.5%)). Of these, seven requested a period of relative silence prior to the initial appointment. A further four audiologists who did not perform PTA also requested a period of relative silence prior to the appointment. Across the 11 audiologists the period requested ranged from 12 - 48 hours (mean = 26).

Table 1. Clinical procedures routinely included in audiologists' test battery for musicians.

Assessment Type	**Proportion of Audiologists (n=31)**	
	n	%
Otoscopy	31	100
Pure Tone Audiometry (PTA)	11	35.5
Tympanometry	8	25.8
Speech Discrimination	4	12.9
Extended High Frequency PTA	1	3.2
Speech in Noise Discrimination	1	3.2
Acoustic Reflexes	1	3.2
Oto-acoustic Emissions	-	-
Loudness Discomfort Levels	-	-

There was considerable variation in how musicians obtained their MHP from audiologists. Sixteen audiologits (51.6%) routinely fitted earplugs in an appointment, while 13 (41.9%), did not, delivering them either over-counter or via post. The remaining two audiologists indicated that they would choose their delivery method based on the client's preference. Follow-ups were uncommon with just five audiologists making further contact with the client via phone, email or appointment to check progress.

Provision of counselling on hearing protection for musicians was routinely carried out by 23 (74%) of the audiologists. Of these 23 audiologists, 16 (70%) conducted an informal discussion with the client, 3 (13%) handed out instructional leaflets, and 4 (17%) used both methods. The topics most

frequently mentioned during counselling were: education about sound exposure (13 audiologists (57%)) and hearing conservation practices (6 audiologists (26%)).

Verification of the MHP, in which the attenuation provided by the earplugs was objectively measured, was routinely performed by six audiologists, all of whom compared pure-tone hearing thresholds with and without the earplugs in situ. Use of real-ear-measures was mentioned by two audiologists; however, both noted difficulties with this method of verification and commented on its lack of reliability. An additional two respondents indicated verification would only be undertaken if issues arose. Validation, in which the subjective fit of the hearing protectors was assessed, was routinely carried out by four audiologists; however, only one outlined a procedure for this beyond informal discussion.

Technical aspects of musicians' hearing care

Audiologists and manufacturers were asked to indicate which method of impression taking they chose to use in preparation for making custom MHP, and these results for both groups are shown in Table 2.

For the audiologists, as shown in table 2, the most common method for impression taking was for the jaw to remain closed and stationary, although there was wide variation in responses. Preference for the material used for the otoblock (a safety dam inserted into the ear canal prior to impression taking) was closely divided between cotton and foam, as was the canal length of the MHP between medium and long (see table 2). In terms of viscosity of the impression material, high viscosity was favoured, with 41.9% preferring to use this when taking MHP impressions. For the earplug, the majority of audiologists (80.6%) preferred a soft silicon to be used, with a moderate density, or 'shore' 40, being favoured by 61.3%. It is worth noting that one clinician preferred their earplugs to be made of hard acrylic, and another five were unsure as to their preference. Management features, such as removal pins and coloured tips for identification, had been ordered in the past by 80.6% of

audiologists, with neck-cords (n = 10) and removal pins/handles (n = 18) being the most popular choices.

Table 2. Audiologist and manufacturer preferences for the making of MHP.

	Audiologists (n=31)		Manufacturers (n=4)	
	n	**%**	**n**	**%**
Impression Technique				
Closed jaw, stationary	14	45.2	1	25[1]
Open jaw, stationary	2	6.5	1	25
Open jaw, with motion	3	9.7	1	25
Open jaw, with bite-block	8	25.8	-	-
Other	4	12.9	-	-
No recommendation	-	-	1	25
Impression Material Viscosity				
Low	9	29	1	25
Medium	-	NA[2]	1	25
High	13	41.9	1	25
Unsure	9	29.1	1	25
Otoblock				
Cotton	17	54.8	-	0
Foam	13	41.9	3	75
Either	1	3.2	1	25
Earplug Canal Length				
Short	-	0	-	0
Medium	13	41.9	-	0
Long	15	48.4	4	100
Unsure	3	9.7	-	0

Audiologists were asked to indicate which level of hearing protection they most frequently prescribed. The most commonly prescribed attenuation was 15 dB (n = 13), followed by the highest attenuation, 25 dB (n =8), with only two audiologists preferring ≤10 dB. Just over one in five audiologists (n = 7) indicated that the preference for degree of attenuation was linked to the type of instrument played by the specific musician.

[1] This manufacturer responded with "Other: Neutral impressions going past the second bend," which for the purposes of this survey was classified as closed, stationary.
[2] This option was not provided in the audiologists' survey.

Respondents were invited to elaborate on the attenuation level they would recommend for particular listening situations or instruments, and responses were coded into one of 12 categories. As can be seen in table 3, a small amount of attenuation (≤10 dB) was most often recommended for vocalists or for acoustic or practice settings, but was otherwise rarely prescribed. A moderate degree of attenuation was recommended for 'most' situations, as well as for and classical settings. The highest degree of attenuation, ≥25 dB, was most commonly recommended for percussionists and amplified listening situations.

Table 3. The situations and instruments for which audiologists most commonly recommend each level of attenuation.

	≤10 dB	**15 dB**	**25 dB**
Situations			
Most		29%	9.7%
Amplified			54.8%
Acoustic	22.6%	12.9%	
Classical	9.7%	19.4%	
Practice	16.1%		
Solo	6.5%		
Instruments			
Percussion	-	6.5%	61.3%
Voice	32.3%	16.1%	
Guitar	3.2%	6.5%	6.5%
Brass	-	6.5%	3.2%
String	3.2%	3.2%	
Rarely Prescribed	32.3%	-	9.7%

Furthermore, we investigated which musicians (i.e. players of which musical instruments) presented the 'most difficulty' when fitting MHP. The three instruments most commonly nominated as

presenting the most difficulty in choosing appropriate attenuation and fitting were voice (n = 10), brass (n = 5) and wind (n = 3).

In an open response item, audiologists were asked what they perceived to be the main barriers to musicians using MHP (see table 4). Overwhelmingly, the impact of MHP on the musical experience was reported, followed by a lack of education and awareness and cost.

Table 4. Perceived barriers to use of MHP.

Barriers	Proportion of Audiologists
Impact on music experience	54.8%
Lack of Education	35.6%
Cost	25.8%
Over-attenuation	19.3%
Occlusion	16.1%
Stigma	16.1%
Poor fit/comfort	12.9%
Appearance	9.7%
Over-attenuation	9.7%
Lack of acclimatisation	6.5%
Motivation	6.5%

Post-hoc analyses

Chi-squared tests were performed to investigate if the audiologists' years of clinical experience or previous musical training had affected the survey responses. First, respondents were split into two groups based on experience: those with less than the median of eight years' clinical experience (n=15), and those with eight or more years' experience (n=16). Pearson Chi-squared tests indicated that experienced audiologists were more likely to request a period of relative silence prior to seeing a musician (than non-experienced audiologists (62.5% vs 13.3%), X^2 (1) = 7.89, p=0.005. Likelihood ratio tests indicated that more experienced audiologists were more open to involvement in an upskilling course on the topic (than less experienced audiologists (93.8% vs 66.7%), X^2 (1) = 3.87, p=0.049. They

were also significantly more likely to favour a moderate (15 dB) degree of attenuation when compared to less experienced audiologists (68.8% vs 13.3%), X^2 (1) = 12.19 p=0.007.

While no other results reached significance, there was a general trend observed in many responses, with more experienced audiologists more likely to perform PTA (43.8%) vs 26.7%), verify earplugs (37.5% vs 13.3%), counsel on use (37.5% vs 13.3%) and follow-up on progress (25% vs 6.7%, than those with less experience. Experienced audiologists were also more likely to use cotton as their otoblock as opposed to foam (62.5% vs 46.7%), and 93.8% had ordered management features in the past, as opposed to 66.7% of audiologists with less experience.

Audiologists were then divided into two groups: those who had professional or semi-professional music experience (n=15) and those who did not (n=16). Of the 15 audiologists who had musical experience, 9 had less than 8 years clinical experience. In the case of the 16 audiologists without musical experience, 6 had less than 8 years clinical experience. Analysis of results for these two groups based on musical experience showed no significant differences on the closed response items. However, several trends were noted; audiologists with musical experience were more likely to perform PTA (46.7% vs 25%), request a period of relative silence prior to testing (46.7% vs 25%) and to follow-up on progress (26.7% vs 6.3%). In addition, audiologists with musical experience were more likely to use a method of open-mouth impression taking (53.3% vs 31.3%), and more likely to state that preferred earplug filter depended on the instrument played (40% vs 12.5%). Finally, audiologists with musical experience were less likely to fit earplugs in an appointment as compared with audiologists without musical experience (40% vs 62.5%).

Manufacturer Survey

For the manufacturers, the responses to the closed items on the manufacturer survey are presented in table 2. For two of the items the recommendations offered by manufacturers to audiologists seemed to be in agreement. These were for the use of otoblock, with three companies recommending foam and one recommending either foam or cotton, and the earplug canal length.

For the latter, all of the manufacturers indicated they would recommended a long canal length for their custom MHP. Items over which they were not in agreement however, were the impression technique recommended by manufacturers and the viscosity of the impression material to be used. As can be seen in table 2, a different impression technique was recommended by each manufacturer excluding one that indicated they had no formal recommendation for audiologists on this process. Similarly, a different response was seen from each manufacturer as to the viscosity of the material recommended for taking impressions, with one commenting that they had no specific recommendations for audiologists.

Responses to open survey items revealed that manufacturers placed a great emphasis on the accuracy of impression-taking by the audiologist in order to achieve a well-fitting earplug. For example, "The outcome really depends on the quality that you start with. Good impressions are the key," and "as long the imprint is made by a pro." When asked what advice they might give if the occlusion effect was a problem for a client, three manufacturers made reference to optimising the canal length by extending it beyond the second bend, for example,

> "Provide 'full shell' neutral impressions going well past the second bend free from voids. Occlusion reduction can be done by canal length optimisation and selecting the correct filter for the specific application."

However, one manufacturer provided the opposite response, suggesting that canal length be shortened[3].

Manufacturers were also asked if, and what sort of, recommendations were available to audiologists regarding choosing an appropriate degree of attenuation. One company recommended "on-site noise testing" be conducted and another suggested that the main genre of exposure should determine the filter strength. The remaining respondents either gave no recommendations or

[3] A request was made by the author to clarify the response and the answer was repeated.

requested the audiologist contact them directly for support. In terms of design options for management and handling of MHP, three of the four companies offered style variations such as neck cords, handles or removal lines.

Discussion

The aim of this study was to gain insights into the clinical practice of providing hearing care for musicians by surveying audiologists and manufacturers of hearing protectors for musicians. Overall, the main finding was that whilst audiologists reported high confidence in providing care for musicians, there was considerable variation in the manner in which this care was provided. Despite the majority of audiologists (87%) feeling confident in their ability to care for musicians, 81% also expressed interest in having further training on the topic – an encouraging finding which suggests that audiologists are eager to know more about this specialised practice area:

> "When I said I'm 'highly confident' I'm very aware there's A LOT more I could learn on this specific topic and would love a CPD [continuing professional development] event covering this."

There was also variation in responses to the manufacturer survey, with great diversity in both the manufacturing of MHP and recommendations by manufacturers to audiologists on their preferred impression technique.

It was clear that not all audiologists associated an impression appointment for MHP with the need for a hearing assessment. In fact, PTA was conducted by only 35% of audiologists prior to advising on hearing protection. While the reasons for individual audiologists not conducting a PTA were not directly explored , open-ended responses did suggest that audiologists were assuming that PTA was not wanted by clients: 'Musicians are often poor and do not want a hearing test as well as ordering the muso earplugs.' It could be argued that providing hearing protection does not require knowledge of the client's hearing thresholds. However, we would suggest that, ideally, MHP should be provided as part of a holistic package of hearing healthcare that covers all aspects of musicians' hearing

wellness. In this case, monitoring the impact of noise exposure via audiometry should be regarded as a crucial element in the overall care of musicians' hearing. In some circumstances, time and/or cost pressures may exist that do not allow for a full hearing test to occur. In such instances, oto-acoustic emissions could be a viable tool for hearing screening, yet these were very rarely performed by our cohort.

The inclusion of extended diagnostics in the test battery for musicians was also rarely seen. Common tests such as speech discrimination were performed by only 13% of audiologists, and acoustic reflexes, which are less common generally, were performed by only one audiologist. The testing of extended high frequency hearing beyond the traditional speech frequency range was also uncommon, again performed by only one audiologist in the sample. Testing these frequencies, however, could arguably be of great value to the care of a musician; not only are they implicated in detecting early onset NIHL (Rocha et al., 2010; Luders et al., 2013; Mehrparvar et al., 2014), these frequencies also carry the musical overtones that contribute to the perception of the quality and timbre of music (Emiroglu & Kollmeier, 2017). For a client wanting to experience the full range of sounds, not just speech frequencies, this information could both guide and inform a hearing conservation plan, yet this is not being performed at the clinical level.

For delivery of MHP, audiologists were divided, with half providing the earplugs routinely in an appointment and the remainder either posting out or leaving for client collection. We would argue that these appointments are crucial as they provide both parties with an opportunity for counselling, MHP fit-training, and measurements of validation and verification. Research shows that fit-training for users of custom hearing protectors improves attenuation consistency and fit reliability (Casali & Lee 2017; Tufts et al 2013) In the sample studied here, it was encouraging to note that half the audiologists provided fit-training, but measures of objective verification or subjective validation to ensure successful insertion were performed by only 19% and 13% of audiologists respectively. One possible reason for this can be inferred from the survey comments, suggesting audiologists had low

confidence in the current methods of earplug verification, with several respondents highlighting frustration at the lack of precision in PTA comparisons and probe-tube measures. Simply stated, one respondent commented, "We need better solutions than what we currently have."

An analysis of the survey responses for audiologists with different levels of musical experience and clinical experience did show trends towards a higher level of care being provided by audiologists with more experience in providing hearing healthcare. This was particularly evident for experienced audiologists who were more likely to request a period of relative silence prior to testing, perform PTA, verify earplugs, counsel on hearing protection and follow up clients. They were also more likely to be conservative on the topic of over-attenuation, favouring the medium amount of attenuation far more than inexperienced audiologists. A similar bias towards high-level care in those with musical experience was also evident in the results. Again, these audiologists were more likely to request a period of relative silence, perform PTA and follow-up on progress as compared to audiologists without musical experience. They were also more likely to use open-mouth impression techniques, methods known to help create a tighter, more closely fitted earplug (Pirzanski, 2006). They were also more likely to comment that choosing the amount of attenuation depended heavily on the instrument that the musician played, perhaps reflecting their deeper knowledge of music practice. Surprisingly, we found that audiologists with musical experience were less likely to personally fit hearing protection to clients, and more likely to post them to the client. It is difficult to explain this trend, but it could be seen as an indication that the audiologists with musical experience were confident in their clients' ability to use the protection, or alternatively, it could reflect an assumption on the part of the audiologists that musicians are less able to afford the time or money for additional appointments.

On surveying manufacturers, it was clear that great responsibility was placed on the audiologist to create a quality ear impression. For technical issues such as otoblock use or canal length of the earplug, almost all manufacturers agreed on the use of foam and long canal length respectively.

However for key steps, such as impression technique or the viscosity of the impression material, both factors known to influence the fit of the final earplug (Pirzanski, 2006; Maltby, 2016), a range of responses were recorded. It is not clear if the differences in responses indicate a fundamental disagreement amongst manufacturers or reflect simply differences in manufacturing processes or products. Audiologists also showed variation in how they went about preparing for MHP. Differences in manufacturer versus audiologists responses on this topic have previously been reported by Hurley (2015), and leaves open the question of best practice.

Audiologists most frequently reported difficulty fitting MHP for musicians who played instruments that involve vocalisation, either directly or as a by-product of playing, i.e., voice, brass and wind. It is well recognised that players of these instruments are more likely to nominate the occlusion effect as a negative aspect of wearing earplugs than musicians playing other instruments. For these players, the intensity of the occlusion effect is directly linked to the canal length and seal of the musicians' earplug (Killion, 2012). Earplugs with a shallow fit provide greater room for amplification of internalised low-frequency sounds, often interpreted as over-powering and intolerable to the musician. This has been demonstrated to lead to earplug rejection (Laitinen & Poulsen, 2008). However, it has also been documented that the occlusion effect can be managed (at least in part) with insertion of the earplug beyond the second bend of the ear canal (Killion, 2003; Lee, 2011; Pirzanski, 2006). It is concerning then, that although most manufacturers recommended a long canal length in our survey, almost half of audiologists routinely ordered medium-sized canal lengths. As a result, the likelihood of musicians experiencing the occlusion effect is increased, as is their risk of rejecting their hearing protectors.

When considering the results of this study the potential for response bias should be taken into account. The sample of audiologists who completed the survey included a high proportion of musically experienced audiologists. The survey content itself seems to have attracted audiologists with a personal interest in the study aims, and as a result the conclusions drawn may not be

generalisable to the broader audiologist community. Furthermore, the small sample size likely contributed to the paucity of statistically significantly results obtained, although trends in responses were evident.

Conclusion

This study investigated the standard of hearing healthcare provided to musicians in Australia by clinical audiologists and manufacturers of MHP. These results have identified a number of gaps in information, practice processes and professional training that could negatively influence outcomes of use of hearing protection by musicians. Despite the existence of excellent resources to guide MHP practice (e.g. Chasin, 2009), it is not necessarily evident that such tools have influenced practice at the clinical level. These results reveal the need for implementation of findings and provision of training at the clinical level. In fact the results of this study suggest that the majority of audiologists would welcome further training opportunities that might help inform their care of musicians. As an industry, if we wish to support musicians in the use of MHP and conservation of their hearing, then it would seem we need to start with the support of those providing them with this care.

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